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ON NONLINEAR STAGE OF PARAMETRIC INSTABILITIES OF WAVES EXCITED BY LOCALIZED PUMPING

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By present time the theory of weak turbulence of homogeneous plasma has been developed well enough. It makes it possible to calculate an anomalous absorption of the electromagnetic wave via parametric instabilities. However, in real experiments the plasma or pumping waves are inhomogeneous, as a rule, and a new stabilizing mechanism, i.e. carrying out of the waves from the interaction region, arises.

The present paper considers the plasma turbulence in a homogeneous medium excited by localized pumping. Such a statement is seemed to be interesting enough. For example, in experiments on high-frequency heating of plasma in large installations the pumping wave is excited by the source of finite size and therefore is localized within well-defined resonance cone [1]. As is shown in [2], under lower hybrid heating in tokamaks just a presence of a resonance cone often defines the threshold of parametric instabilities.

To elucidate the influence of pumping localization on a nonlinear stage of the parametric instability, let us consider the excitation of Langmuir oscillations in an isotropic isothermal plasma. The equations describing the excited turbulence can be written as

$$\frac{\partial n_k}{\partial t} + \vec{v}_T \frac{\partial n_k}{\partial \vec{z}} = n_k \left(\gamma_p(k) - \nu_{ei} + \int T_{kk'} n_{k'} d k' \right) \quad (1)$$

Here n_k is the number of Langmuir plasmons, $\vec{v}_T = 3 v_T (k z_d)$ is their group velocity, $T_{kk'} = \int \left(\frac{\omega - \omega'}{k - k'} \right) \frac{(\vec{k} \vec{k}')^2}{k^2 k'^2}$ is the matrix element of the induced scattering on ions - the main nonlinear process, $\gamma_p(k)$ is the increment of the parametric instability and ν_{ei} the frequency of electron-ion collisions.

in a homogeneous medium the distribution of excited oscillations is sharply anisotropic. The appearing turbulence is the succession of quasimonochromatic waves $n_k = \sum_i \mathcal{N}_i \delta(\vec{k} - \vec{k}_i)$ propagating along the electric field of the pumping wave. Their amplitudes decrease with the wave vector, and the distance between two neighbours is $\Delta k \approx k_{diff} = \nu_d^{-1} \sqrt{\frac{m}{M}}$

It is natural to expect that the weak inhomogeneity will not destroy a general picture of the spectrum, and we can simplify (1) turning to the satellite approximation [3] $\vec{k}_i \parallel \vec{E}_0$, $k_i = k_0 - i k_{diff}$. In dimensionless variables neglecting the difference of group velocities of the various waves, let us write down the following equations (\mathcal{N}^+ and \mathcal{N}^- are the waves propagating in the positive (\mathcal{N}^+) and

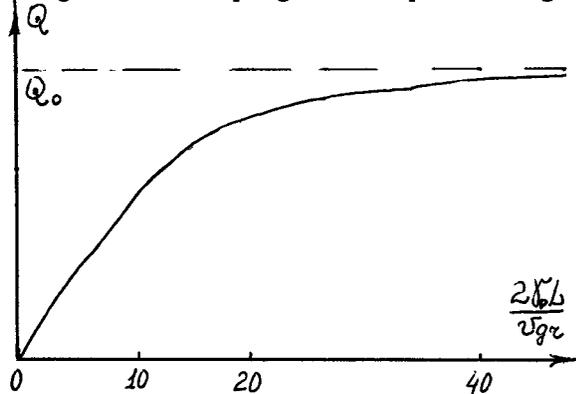
negative (ω^-) directions

$$\frac{\partial \omega_0^\pm}{\partial t} \pm v \frac{\partial \omega_0^\pm}{\partial x} = \omega_0^\pm \left(-\frac{1}{\rho} + 1 - \omega_1^\mp \right)$$

$$\frac{\partial \omega_i^\pm}{\partial t} \pm v \frac{\partial \omega_i^\pm}{\partial x} = \omega_i^\pm \left(-\frac{1}{\rho} + \omega_{i-1}^\mp - \omega_{i+1}^\mp \right) \quad (2)$$

$$V = \frac{v_{g2}}{\omega_p L} ; \quad \rho = \gamma_p / v_{2ei}$$

The behaviour of the solutions of the system (2) was investigated computationally with the use of the implicit difference scheme of the "running calculation" type. It is easy to understand that Eq.(2) has no stationary solutions. Therefore, when solving (2), we use the absorbing boundary conditions modelling the appearance of strong Landau damping or the plasma edge.



The main result of this work is presented in the Figure illustrating the flux energy to the plasma as a function of the parameter $\frac{\gamma_p L}{v_{g2}}$, Q_0 is the energy flux in homogeneous situations. It is seen that as the pumping amplitude increases, the carrying-out of energy from the localization region quickly becomes inefficient. This result can be understood from the following considerations. In the isothermal plasma the parametric instability resulting to the exciting of oscillations is convective, and for its development it is necessary the condition $\frac{\gamma_p L}{v_{g2}} > \Lambda$ to be valid. Here Λ is Coulomb logarithm and γ_p the instability increment. In the

nonlinear regime when $\gamma_p / \gamma_{nc} \sim 1$ the threshold $E_0 = E_{th}$ is only slightly exceeded, therefore the oscillations scatter on ions passing the length v_{g2} / γ_{nc} . It is seen that when the threshold is exceeded by the order of unity, the scattering length is much less than the pumping localization region. As was mentioned above, the scattering on ions is mainly back scattering. Thus the trapping of oscillations occurs, and the carrying out of energy decreases. As is shown in the Figure at $\frac{\gamma_p L}{v_{g2}} \sim 20$ (for the tokamak plasma $\Lambda \sim 15$) the flux energy practically coincides with the calculated one in the approximation of a homogeneous plasma.

So far excitation of oscillations was considered for an isotropic plasma. This situation is typical for laser heating. Under lower hybrid heating of plasma in tokamaks the main nonlinear process for exciting magnetized plasmons ($\omega = \omega_p k_z / k$) is also the induced scattering, but the oscillations are scattered at the angle about $\theta \sim \frac{v_{g2}}{v_{ph}}$. Qualitatively this situation is similar to that described above, and when calculating an anomalous absorption of the pumping wave (4), there is no need to take into account its localization in space. Thus, the resonance cone deformation due to the modulation instability of the pumping wave results to a local change of its amplitude and should be considered as a more important effect.

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